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HIGH STRENGTH CONCRETE USING GGBS AND NANO TIO_2

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ABSTRACT

High strength concrete appears to be a better choice for a strong and durable structure. In this project, investigations were carried out on durable and strength properties of M80 grade of HSC mixes with different replacement levels, such as 10%, 20%, 30% and 40% of GGBS with cement and optimum percentage level of GGBS constant and sand are replaced with GBS by different level 10%, 30%, 50%, 70%, 90%. Keeping both optimum percentage levels of GBS and GBS is constant and cement replaced with Tio_2 with different level 1%, 2%, 3%, 4%, 5% by cement replacement. The HSC mix, grade M80 concrete is designed as per ACI 211. 4R-08 Guide for selecting proportions for high strength concrete with Pozzolana Portland cement and other cementitious materials. The result of these investigations demonstrates the strength characteristics of GGBS based concrete mixes. Based on the results obtained, the replacement of 20% of GGBS, and 70% GBs with 3% of Tio_2 which superior strength characteristics were arriving with compared to conventions concrete.

KEYWORDS: High Strength Concrete, Ground Granulated Blast Furnace Slag, GBs, Tio_2

INTRODUCTION

Concrete is a durable and versatile construction material. It is not only strong, economical and takes the shape of the form in which it is placed, but it is also aesthetically satisfying. High strength concrete is a concrete mixture, which possess high durability and high strength when compared to conventional concrete. This concrete contains one or more of cementitious materials such as fly ash, Silica fume or ground granulated blast furnace slag and super plasticizer.

Concrete is probably the most extensively used construction material in the world. However, when the high range water reducer or super plasticizer was invented and began to be used to decrease the water/cement (w/c) or water/binder (w/b) ratios rather than being exclusively used as fluid modifiers for normal-strength concretes, it was found that in addition to improvement in strength, concretes with very low w/c or w/b ratios also demonstrated other improved characteristics, such as higher fluidity, higher elastic modulus, higher flexural strength, lower permeability, improved abrasion resistance, and better durability. This fact led to the development of HPC. HPC is the latest development in concrete. It has become more popular these days and is being used in many prestigious projects such as Nuclear power projects, flyovers, multistoried buildings.

Since 1990s, HPC has become very popular in construction works. At present, the use of HPC has spread throughout the world. In 1993, the American Concrete Institute (ACI) published a broad definition for HPC and is defined as the concrete which meets special performance and uniformity requirements that cannot always be achieved by using only the conventional materials and mixing, placing and curing practices. The performance requirements may involve

enhancements of placement and compaction without segregation, long-term mechanical properties, early age strength, toughness, volume stability, or service life in severe environments. Theaddition of mineral admixture in cement has dramatically increased along with the development of concrete industry, due to the consideration of cost saving, energy saving, environmental protection and conservation of resources. However, environmental concerns both in terms of damage caused by the extraction of raw material and carbon dioxide emission during cement manufacture have brought pressures to reduce cement consumption by the use of supplementary materials. Mineral admixtures such as fly ash, rice husk ash, silica fume etc. are more commonly used in the development of HPC mixes. They help in obtaining both higher performance and economy. These materials increase the long term performance of the HPC through reduced permeability resulting in improved durability. Addition of such materials has indicated the improvements in the strength and durability properties of HPC.

Significance and Objectives The objectives of the present investigation is to develop a simplified mix design procedure, specially for HPC by varying the percentage replacement of cement by GGBS (0%, 10%, 20%, 30%), GBS (10%, 30%, 50%, 70%, 90%) and nano Titanium dioxide(1%, 2%, 3%, 4%) at a constant dosage of super plastisizer, based on BIS and ACI code methods of mix design procedure and available literatures on HPC. Investigations are carried out on the above procedure to produce HPC in mixes for M80 and M100 grades using 12. 5 mm maximum size of aggregates to ascertain workability and the mechanical properties of the designed mixes and to find an optimum cements replacement by GBS, GGBS, nano TiO_2. Hence in the present investigation more emphasis is given to study the HPC using GBS, GGBS and nano TiO_2 so as to achieve better concrete composite.

LITERATURE REVIEW

Maria Kaszynska investigated that hydration heat of cement was carried out in the calorimeter, in adiabatic conditions. **K. Arunachalam** had investigated specifications restrict the replacement level of cement with fly ash to about 25-35%. **MetinHusem** investigated the variation of compressive and flexural strengths of ordinary and high strength micro concrete at high temperatures was examined. **Ali Behnood, HasanZiari** studied on the effect of different amounts of silica fume (SF) and water to cement ratios (w/c) on the residual compressive strength of high strength concrete after exposure to high temperatures. **FuatKoksal, FatihAltun** had investigated those changes on some mechanical properties of concrete specimens produced by using silica fume and steel fiber. The main objective of this work is to obtain a more ductile, high strength concrete produced by using both silica fume and steel fiber. **J. J. Brooks, M. A. MegatJohari** investigated that the effect of silica fume (SF), metakaolin (MK), fly ash (FA) and ground granulated blast-furnace slag (GGBS) on the setting times of high strength concrete has been investigated using the penetration resistance method. **AliNazari et al.,**investigated that the split tensile and flexural strength together with the time setting of concrete by partial replacement of cement with nano-phase TiO_2 particles. **ShadiRiahi** investigated the effect of curing; medium on microstructure together with physical, mechanical and thermal properties of concrete containing Al_2O_3nano particles has been investigated.

E. Aryan, O. Saatcioglu studied on the optimization of compressive strength of steel fiber reinforced high strength concrete (SFRHSC) by statistical design and analysis of experiments. **Patil1, P. D. Kumbhar** had studied the effect of the addition of materials on the strength and durability properties of concrete. **MostafaJalal, Mojtaba Fathi** had investigated the strength enhancement and durability-related characteristics along with theological, thermal and micro structural properties of high strength concrete (HSC) containing nano TiO_2 and industrial waste ash namely as fly ash

(FA). **FereshtehAlsadatSabet, Nicolas Ali Libre** had investigated the effect of natural zeolite, silica fume and fly ash on the properties of fresh and hardened concrete. Slump flow, super plasticizer demand, compressive strength, electrical resistivity, water absorption and chloride permeability was measured for all mixes.

MATERIALS AND THEIR PROPERTIES

Cement

The cement used is Zuari OPC 53 grade cement. The Ordinary Portland Cement of 53 grades conforming to IS:8112-1989is is use. Tests were conducted on cement like Specific gravity, consistency tests, setting tests, Compressive strength N/mm^2 at 28 days. Properties of cement shown in table 1

Fine Aggregate

Fine Aggregate for the Experimental Program had been locally obtained and conformed to grading Zone II as per IS:383-1970. Fine Aggregate was initially sieved through 4. 75 mm sieve to remove any particles greater than 4. 75 mm after which it was washed to remove and dust. Physical properties of fine aggregates are shown Table 1

Coarse Aggregate

Course aggregate was initially sieved through 20 mm passing sieve to remove any particles greater and were tested as per Indian Standard Specifications IS: 383–1970. Physical properties of course aggregates are shown in Table 1.

Ground Granulated Blast Slag (GGBS)

Ground Granulated blast furnace slag is a glassy granular material formed when molten blast furnace slag is rapidly chilled, as by immersion in water. The cementations action of a granulated blast furnace slag is dependent to large extent on the glass content. GGBS hydrates are generally found to be more gel like than the products of hydration of Portland cement, so it denses the cement paste. Confirming to IS 12089:1981 for (cement replacement) Properties of Ground Granulated Blast Slag (GGBS**)** show in table 1

GBS

Confirming to I. S 2386 Part VII for (Sand replacement) Properties of GGBS show in table 1

Nano-TiO2 particles

Nano–TiO2 with average particle size of 15 nm was used as received. Properties of tio2 show in table 1.

Super Plasticizer

Super plasticizer MASTER GLENIUM SKY 8233, based on poly carboxylic ether, complies with IS 9103-999and ASTM C-494 [6] was used.

Water

In this project, casting and curing of specimens were done using potable water which shall be free from deleterious materials. Water plays an important role in concrete production (mix) in that it starts the reaction between the cement and the water. It helps in the hydration of the mix.

Table 1: Properties of Materials

Particulars	Properties
Cement	Specific gravity- 3. 15, Normal consistency- 33%, Initial setting time-60mins, Final setting time-350mins. Fineness-384m2/kg Compressive strength - 56N/mm^2
GGBS	Colour - Off-white powder, Bulk density (loose) - 1. 0–1. 1 tonnes/m^{3,} Bulk density (vibrated) - 1. 2–1.3 tones/m^{3,} Relative density - 2. 85–2. 95, Surface area - 400–600 m^2 /kg
Tio_2	Bulk Density-4. 23g/cm^3, Fracture Toughness - 3. 2 Mpa. m$^{-1/2}$, Molar Mass -79. 9378 g/mol
Sand	Specific gravity -2. 57, Fineness modulus -2. 64, Bulk density (Kg/m^3)-1753
Coarse aggregates	Specific gravity -2. 704, Fineness modulus -6. 45, Bulk density (Kg/m^3)-1670
GBS	Glass content Vol. - 60. 4 - 100. 0%, True density -2. 796 - 3. 070 g/cm^3 Apparent density-3 2. 021 - 2. 843 g/cm, Bulk density 0. 689 - 1. 427 g/cm^3 Porosity Vol. - 2. 5 - 31. 2%

EXPERIMENTAL PROGRAM

Mix Design

In these investigations concrete mix design (M80) was designed based on ACI 211. 4R-2008. this code presents a generally applicable method for selecting mixture proportion for high strength concrete and optimizing this mixture proportion on basis of trial batches. The method is limited to high strength concrete production using conventional materialsand production techniques. Mix proportioning details are given below in table 2.

Table 2

	Cement (Kg)/m^3	Water lt/m^3	Sp lt/m^3	CA kg/m^3	FA kg/m^3	SF kg/m^3	ggbs %	GGBS kg/m^3	gbs %	GBS kg/m^3	Tio_2	Tio_2 kg/m^3
M1	504	126	7.56	1359.86	513.34	10.08	0	0	0	0	0	0
M2	453.6	126	7.56	1359.86	513.34	10.08	10	50.04	0	0	0	0
M3	403.2	126	7.56	1359.86	513.34	10.08	20	100.8	0	0	0	0
M4	352.8	126	7.56	1359.86	513.34	10.08	30	151.2	0	0	0	0
M5	403.2	126	7.56	1359.86	462.006	10.08	20	100.8	10	51.334	0	0
M6	403.2	126	7.56	1359.86	359.338	10.08	20	100.8	30	154.002	0	0
M7	403.2	126	7.56	1359.86	256.67	10.08	20	100.8	50	256.67	0	0
M8	403.2	126	7.56	1359.86	154.002	10.08	20	100.8	70	359.338	0	0
M9	403.2	126	7.56	1359.86	51.334	10.08	20	100.8	90	462.006	0	0
M10	398.97	126	7.56	1359.86	154.002	10.08	20	100.8	70	359.338	1	4.03
M11	394.94	126	7.56	1359.86	154.002	10.08	20	100.8	70	359.338	2	8.06
M12	390.91	126	7.56	1359.86	154.002	10.08	20	100.8	70	359.338	3	12.09
M13	386.88	126	7.56	1359.86	154.002	10.08	20	100.8	70	359.338	4	16.12

Mixing Procedure

- A pan mixer machine (40 kg capacity) is used to mix UHPC.
- Dry ingredients i.e., cement, Ground Granulated Blast furnace Slag, are placed in the mixer and mixing is done for 3 minutes. Nano titanium dioxide is stirred by mixing 10% of water at high speed (120 rpm) for one minute and it is added in the mix. Then
- GBS is added and mixed for one minute. Then 70% of water along with half of SP is added and mixed for 2 minutes.
- When proper blending of ingredients is observed, remaining SP and water is added and mixed for 3 minutes.
- When foldable consistency is observed, steel fibers are added slowly then mixing is continued for 2 minutes

Specimen Preparation and Curing

For each mix 6 cubes, 2 cylinders and 2 beams are cast. Size of cube is 100mm×100mm×100mm and cylinder size is 100mm dia × 200mm and beams of 100mm×500mm×100mm.Curing of cubes, cylinders and beam is done in normal water up to 28 and 56 days.

Testing

Cubes, cylinders and beams are tested for compressive strength and split tensile strength and flexural strength at 28 days and 56 days respectively. They are tested under Compression Testing Machine (CTM) for compressive strength and split tensile strength and Universal Testing Machine (UTM) for Flexural strength

RESULTS AND DISCUSSIONS

Compressive Strength

Compressive strength of all M80Gradeconcretemixtures was determined at 28 days and 56 days of curing and their results are listed in Table 3. As GGBS quantity was increased correspondingly compressive strength was increased up to 20% GGBS. Because compressive strength later on went decreasing by increase in GGBS percentage. It is clearer from the Table 3 that M3 (20% GGBS) for 28 days is 87.6 MPa and at 56 days is 88.8 MPa respectively. Compressive strength of M3 (20% GGBS) is 5.54% more than that of Control mix (M1). Compressive strength of M3 (20% GGBS) at 56 days is 5.996 % more than that of M1 control mix.

Table 3: Compressive Strength of GGBS Test Results

Concrete Mixes	% of GGBS	Compressive Strength	
		28 Days	56 Days
M10	0%	83	83. 8
M11	10%	85. 5	86. 95
M12	20%	87. 6	88. 8
M13	30%	86. 7	87. 9

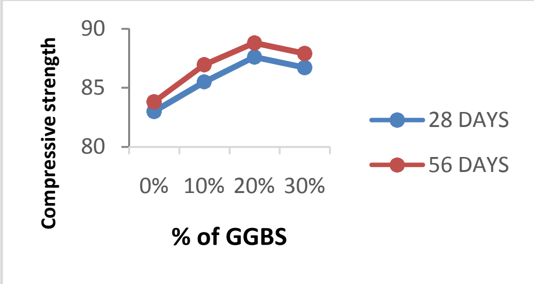

Figure 1: variation of Compressive Strength versus % of GGBS in High Strength Concrete

Compressive strength was studied with 10%, 30%, 50%, 70% and 90% with 20% of GGBS and the results are shown in table 4. It was observed that Maximum compressive strength was obtained by M8 (20% GGBS and 70% GBS) is 94.89N/mm^2 which is 14.32% more than that at 28days and Maximum compressive strength obtained by M8 is 96. 84 N/mm^{2}which is 15.32% more than that at 56 days compared to control mix (M1).

Table 4: Compressive Strength of GBS Testing Results

Concrete Mixes	% of GGBS	% of GBS	Compressive Strength	
			28 Days	56 Days
M5	20%	10%	88.3	89.23
M6	20%	30%	90.23	91.45
M7	20%	50%	92.03	94.3
M8	20%	70%	94.89	96.84
M9	20%	90%	91.31	95.21

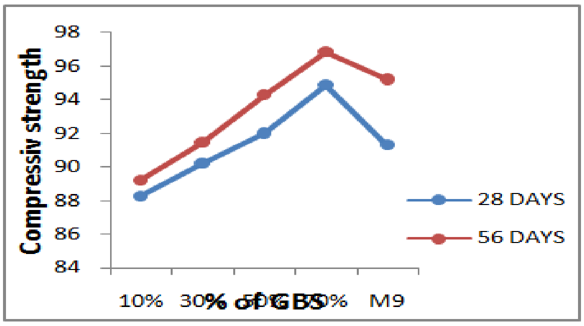

Figure 2: Variation of Compressive Strength Versus % of GBS in High Strength of Concrete

Table 5: Compressive Strength of tio$_2$ Testing Results

Concrete Mixes	% of Ggbs	% of Gbs	% of Tio$_2$	Compressive Strength	
				28 Days	56 Days
M10	20%	70%	1%	95.98	97.62
M11	20%	70%	2%	97.67	99.82
M12	20%	70%	3%	99.03	102.2
M13	20%	70%	4%	97.51	100.31

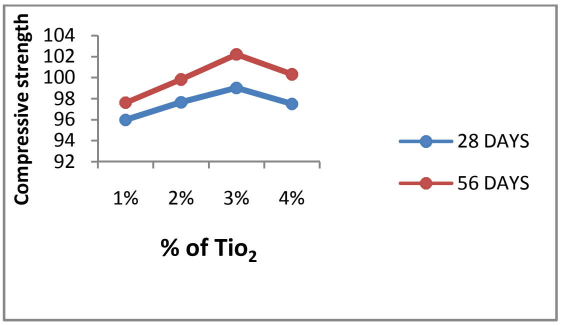

Figure 3: Variation of Compressive Strength Versus % of Tio_2 in High Strength Concrete

Compressive strength of M80 Gradeconcrete were study with 1, 2, 3 and 4% of tio_2and70 % with 20% of GGBS are shown table 5. It was observed Maximum compressive strength obtained by M12 is 99. 03N/mm^2 with is more than 19. 32% at 28days and Maximum compressive strength obtained by M12 is 102. 2 N/mm^{2}with is more than 20. 32% at 56 days compared to control mix. Figure 3 show Variation of compressive strength for Tio_2.

Split Tensile strength

Split Tensile strength of M80 Grade concrete. Split Tensile strength results of all concrete mixtures determined at 28 and 56 days of curing are listed in Table 6 Split Tensile strength was increased with increase of GGBS up to 20% and then decreased as compared with the control mixture. Maximum Split Tensile strength obtained by M3 is 7.2 N/mm^2 with is more than 14. 46% at 28days and Maximum Split Tensile strength obtained by M3 is 8.1 N/mm^{2}with is more than 16.54% at 56 days compared to control mix. Figure 4 show Variation of compressive strength for GGBS.

Table 6: Split Tensile Strength of GGBS Testing Results

Concrete Mixes	% of GGBS	Split Tensile Strength	
		28 days	56 days
M1	0%	6. 36	6. 95
M2	10%	6. 99	7. 8
M3	20%	7. 28	8. 1
M4	30%	7. 02	7. 8

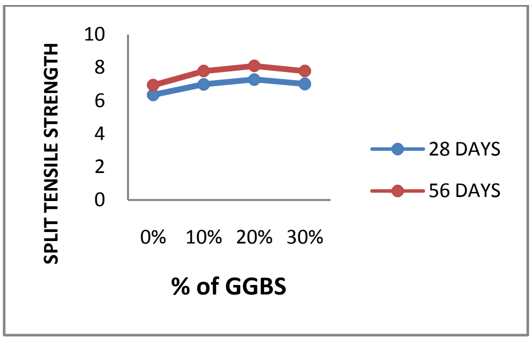

Figure 4: Variation of Split Tensile Strength versus % of GGBS in High Strength Concrete

Split Tensile strength were study with 10, 30, 50, 70 and 90% with 20% of GGBS are shown table 7. It was observed Maximum Split Tensile strength obtained by M8 is 7. 6N/mm^2 with is more than 19. 9% at 28days and Maximum Split Tensile strength obtained by M8 is 8. 35 N/mm^{2}with is more than 15. 32% at 56 days compared to control mix.. Figure 5 show Variation of Split Tensile strength for GBS.

Table 7: Split Tensile Strength of GBS Testing Results

Concrete Mixes	% of GGBS	% of GBS	Split Tensile Strength	
			28days	56days
M5	20%	10%	7.15	7.98
M6	20%	30%	7.3	8.1
M7	20%	50%	7.45	8.25
M8	20%	70%	7.6	8.35
M9	20%	90%	7.4	8.2

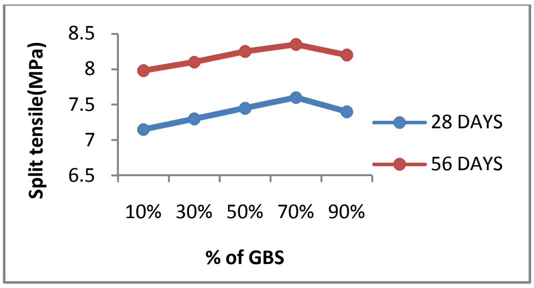

Figure 5: variation of Split tensile Strength Versus % of GBS in High Strength Concert

Table 8: Split Tensile Strength of Tio_2 Testing Result

Concrete mixes	% of GGBS	% of GBS	% of Tio2	Split Tensile strength	
				28 days	56days
M10	20%	70%	1%	7. 52	8. 35
M11	20%	70%	2%	7. 65	8. 48
M12	20%	70%	3%	7. 8	8. 62
M13	20%	70%	4%	7. 72	8. 51

Split Tensile strength of M80 Gradeconcrete were study with 1, 2, 3 and 4% of tio_2and70 % with 20% of GGBS are shown table 8.. It was observed Maximum Split Tensile strength obtained by M12 is 7. 8N/mm^2 with is more than 22. 62% at 28days and Maximum Split Tensile strength obtained by M12 is 8. 62 N/mm^{2}with is more than 24. 028% at 56 days compared to control mix. Figure 6 show Variation of Split Tensile strength for Tio_2.

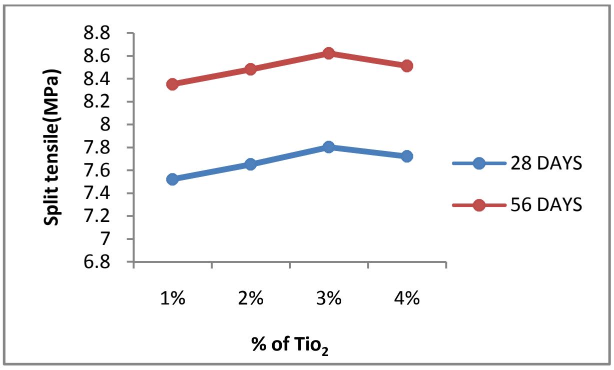

Figure 6: Variation of Split Tensile Strength versus % of Tio_2 in High Strength Concrete

Flexural Strength

Table 9: Flexural Strength of GGBS Testing Results

Concrete Mixes	% of GGBS	Flexural Strength	
		28 Days	56 Days
M1	0%	5.1 8	5.28
M2	10%	5.2	5.49
M3	20%	5.4 2	5.63
M4	30%	5.3	5.48

Flexural strength of M80 Grade concrete. Flexural strength results of all concrete mixtures determined at 28 and 56 days of curing are listed in Table 9 Flexural strength was increased with increase of GGBS up to 20% and then decreased as compared with the control mixture. Maximum Flexural strength obtained by M3 is 5. 42N/mm^{2}with is more than 4. 63% at 28days and Maximum Flexural strength obtained by M3 is 56. 3 N/mm^{2}with is more than 6. 62% at 56 days compared to control mix. Figure 7 show Variation Flexural strength for GGBS.

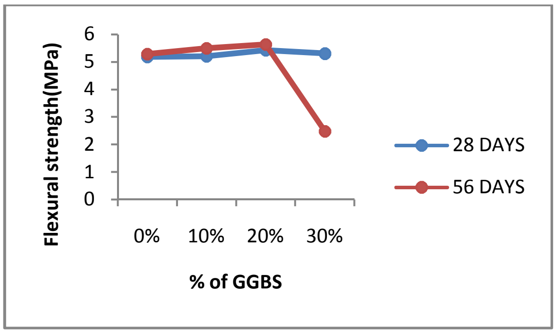

Figure 7: Variation of Flexural Strength versus % of GGBS in High Strength Concrete

Table 10: Flexural Strength of GBS Testing Results

Concrete Mixes	% of GGBS	% of GBS	Flexural Strength	
			28 Days	56 Days
M5	20%	10%	5.52	5.74
M6	20%	30%	5.63	5.82
M7	20%	50%	5.7	5.93
M8	20%	70%	5.82	6.09
M9	20%	90%	5.76	5.97

Flexural strength were study with 10, 30, 50, 70 and 90% with 20% of GGBS are shown table 10. It was observed Maximum Flexural strength obtained by M8 is 5. 82N/mm^2 with is more than 12. 35% at 28days and Maximum Flexural strength obtained by M8 is 6. 09 N/mm^{2}with is more than 15. 34% at 56 days compared to control mix. Figure 8 show Variation of Flexural strength for GBS.

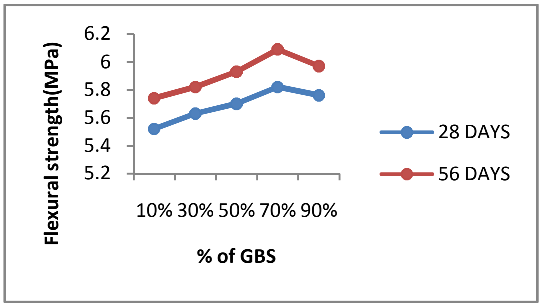

Figure 8: Variation of Flexural Strength versus % of GBS in High Strength Concrete

Table 11: Flexural Strength of Tio_2 Testing Results

Concrete Mixes	% of GGBS	% of GBS	% of Tio2	Flexural strength	
				28 days	56 days
M10	20%	70%	1%	5. 89	6.12
M11	20%	70%	2%	6	6.21
M12	20%	70%	3%	6. 21	6.29
M13	20%	70%	4%	6. 13	6.21

Flexural strength of M80 Gradeconcrete were study with 1, 2, 3 and 4% of tio_2and70 % with 20% of GGBS are shown table 11. It was observed Maximum Flexural strength obtained by M12 is 6. 11N/mm^2 with is more than 17. 95% at 28days and Maximum Flexural strength obtained by M12 is 6. 29 N/mm^{2}with is more than 19. 12% at 56 days compared to control mix. Figure 1 show Variation of Flexural strength at all concrete mixes. Figure 9 show Variation of Flexural strength for $Tio_{2.}$

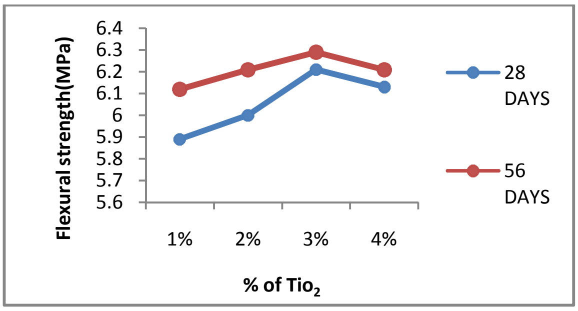

Figure 9: Variation of Flexural Strength versus % of Tio_2 in High Strength Concrete

CONCLUSIONS

- Compressive strength of M3 (20% GGBS) is 87.6 N/mm^2 with is more than 5.54% of Control mix (M1) at 28 days. Compressive strength of M3 (20% GGBS) is 88.8 N/mm^2 more than 5.99% of control mix at 56 days.
- Maximum compressive strength was obtained by M8 (20% GGBS and 70% GBS) is 94.89 N/mm^2 which is 14.32% more than that at 28 days and Maximum compressive strength obtained by M8 is 96. 84 N/mm^2 which is 15.32% more than that at 56 days compared to control mix.
- Maximum compressive strength obtained by M12 (3% Tio_2, 20% GGBS and 70% GBS) is 99. 03N/mm^2 with is more than 19. 32% at 28days and Maximum compressive strength obtained by M12 is 102. 2 N/mm^{2}with is more than 20. 32% at 56 days compared to all mixes.
- Split Tensile strength of M3 (20% GGBS) is 7.28 N/mm^2 with is more than 14.46 % of Control mix (M1) at 28

days. Split Tensile strength of M3 (20% GGBS) is 8.1 N/mm^2 more than 16.54% of control mix at 56 days.

- Maximum Split Tensile strength obtained by M8 (20% GGBS and 70% GBS) is 7. 6N/mm^2 with is more than 19. 9% at 28days and Maximum Split Tensile strength obtained by M8 is 8. 35 $N/mm^2$with is more than 15. 32% at 56 days compared to control mix.
- Maximum Split Tensile strength obtained by M12 (3% Tio_2, 20% GGBS and 70% GBS) is 7. 8N/mm^2 with is more than 22. 62% at 28days and Maximum Split Tensile strength obtained by M12 is 8. 62 $N/mm^2$with is more than 24. 028% at 56 days compared to all mixes.
- Flexural strength of M3 (20% GGBS) is 5.42 N/mm^2 with is more than 4.63% of Control mix (M1) at 28 days. Flexural strength of M3 is 88.8 N/mm^2 more than 5.99% of control mix at 56 days.
- Maximum Flexural strength obtained by M8 is 5. 82N/mm^2 with is more than 12. 35% at 28days and Maximum Flexural strength obtained by M8 is 6.09 $N/mm^2$with is more than 15. 34% at 56 days compared to control mix.
- Maximum Flexural strength obtained by M12 is 6. 11N/mm^2 with is more than 17. 95% at 28days and Maximum Flexural strength obtained by M12 is 6. 29 $N/mm^2$with is more than 19. 12% at 56 days compared to control mix

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